# Towards Epistemic Autonomy in Adaptive Biomimetic Middleware for Cooperative Sensornets

Thesis by
Zenon Chaczko

In Partial Fulfillment of the Requirements
for the Degree of
Doctor of Philosophy University of Technology, Sydney

University of Technology, Sydney
New South Wales, Australia

13 August 2009

## CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidate

_____

# Acknowledgements

It was a rather long and tiring journey of research study towards the doctoral degree that has approached its final stages now. I am eternally grateful to many people for their support in so many ways. First and foremost, I would like to express my deep gratitude to my advisers, Prof Robin Braun, Dr Johnson Agbinya, Prof Subash Challa for their mentorship, guidance and friendship. Their knowledge and dedication have truly enlightened me on this research and positively impacted on my academic career. I owe a special debt to the late Prof John Hughes who supported me in getting my doctoral study started. I would like to express enormous gratitude to my friends and collaborators: Dr Ryszard Klempous, Dr Jan Nikodem, Mr Christopher Chiu, Mr Michal Nikodem, Prof Jerzy Rosenblit, Prof Witold Jacak, Dr Perez Moses and Prof Germano Resconi. I am really indebted to A/Prof Elaine Lawrence for her ongoing support in the final stages of my candidature and Mrs Gail Wightman for helping in initial proofreading the thesis. My thanks go to many friends and members of my family who have offered me support in many forms. My deepest sincere gratitude belongs to my wonderful and loving wife Margaret, daughter Janette, my sons: Emil and Peter, my mother and my late father as well as all other members of my family, for their ever-present love, patience, understanding and unfailing support through all those years.

# Abstract

The importance of studying biomimetic models of software infrastructure for sensornet systems lies in the fact that they are not entirely formal models and thus have to cover a range of issues of epistemic autonomy as well as linguistic and mental adaptation. This adaptation considers the context of software ability to reflect upon the verifiability and validity of its actions and measurements. This research elucidates and explores epistemological consequences of embodying biological autonomic patterns in software architectural models. Autonomy in software systems is a complex issue that raises many fundamental inquiries. The proposal is to initially concentrate on transformations of biological paradigms into epistemological queries and then adapt suitable biomimetic mechanisms into the development of software structure and ethology. Such methodology has proven to be very successful in the design of many engineering systems. The approach leads to a better understanding of the ontology of biomimetic patterns in software as well as a confirmation of requirements validity and design verifiability of autonomous software systems. In a dynamic, cooperative but often hostile environment, a software system infrastructure requires autonomic abilities to execute its normal operations, detect faults and perform necessary recovery actions without the need for external intervention. We approach this problem from the point of view of cognitive and mimetic systems research. The simplest way to make an autonomous and adaptive sensornet system is to include a hierarchy of layers in its middleware, not only to monitor activities of its components but to learn and adapt new behavioural patterns of these components in a changing environment. There are situations, however, where the components will not be able to adapt, learn new behaviour and evolve by themselves. For instance, these may not have yet encountered the new situation while others already have. A solution to this problem is to distribute the new behaviour to neighbouring elements via direct and indirect stigmergy mechanisms so that collaborating components can mutually improve their individual and team performance. The main objective is to disallow distribution of multiple versions of the software components and rather allow each software component to acquire and share with others, new "skills". The components have to compare/verify these new behavioural patterns against their own set of beliefs, desires and intentions. In this thesis we intend to present simulations to test the learning capability of biomimetic algorithms, build a proof-of-concept middleware solution and demonstrate that such systems can not only adapt and evolve but they are robust and highly interoperable (co-operative). The thesis also assesses the suitability of various biomimetic design patterns and algorithms for building autonomic software infrastructure systems for cooperative networked agents.

# Contents

# List of Algorithms

# List of Figures

# List of Tables